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1964

Wildland Research Plan For California

STATE OF CALIFORNIA
RESOURCES AGENCY
DEPARTMENT OF CONSERVATION
DIVISION OF FORESTRY

in cooperation with

UNIVERSITY OF CALIFORNIA, SCHOOL OF FORESTRY

and

U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE,
PACIFIC SOUTHWEST FOREST AND
RANGE EXPERIMENT STATION
AND
CALIFORNIA REGION

Revised November 1964

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FOREWORD

Burgeoning growth since World War II has brought California many opportunities and unprecedented prosperity. Much of this advance can be attributed to the energy of her people, favorable climate, and vastness of her land, and bountiful wildland resources. But continuing progress is not assured indefinitely without wise management of land and natural resources. Resources and land are not unlimited, and the stresses of growth bring many problems which, if not solved, can seriously affect the future.

The importance of this fact to the 60 million acres of wildland in California was recognized in 1958 when the Wildland Research Plan for California was first adopted. The plan was prepared under sponsorship of the State Board of Forestry by a group of men in public and private circles having firsthand knowledge and a keen interest in wildland resources. After inventorying and studying the situation, these men concluded that if increasing demands for timber, water, forage, wildlife, and outdoor recreation are to be satisfied, it is essential to obtain more knowledge on how to manage the wildlands. A program for intensification of research for this purpose was developed.

Now, six years later, with California still growing at an undiminishing pace, it is well to take stock again. Has the situation changed? How well have the gaps in knowledge been filled? Is current research effort commensurate with the needs? What problems are still crucial, and what new ones have appeared on the horizon? These are the questions that must be answered to plan coordinated effort in wildland research.

The plan presented here is based on a revision of the 1958 plan. It was prepared by the Wildland Research Planning Committee convened by W. B. Carter, Chairman of the State Board of Forestry, who also served as chairman of this committee. Members were: Henry J. Vaux, Dean of the University of California School of Forestry; Fred Dickenson, Director of the University of California Forest Products Laboratory; Keith Arnold and his successor, John R. McGuire, Directors of the U.S. Forest Service's Pacific Southwest Forest and Range Experiment Station; Chas. A. Connaughton, Regional Forester of the U.S. Forest Service; John Callaghan, secretary-manager of the California Forest Protective Association; Robert T. Radford, Chairman of the Watershed Fire Council of Southern California; DeWitt Nelson, Director of the California Department of Conservation; Paul Aurignac, State Board of Forestry; and F. H. Raymond, State Forester. They urge rapid implementation of the plan so that the wildlands of California can continuously yield products and services for the benefit of the general welfare of its people.

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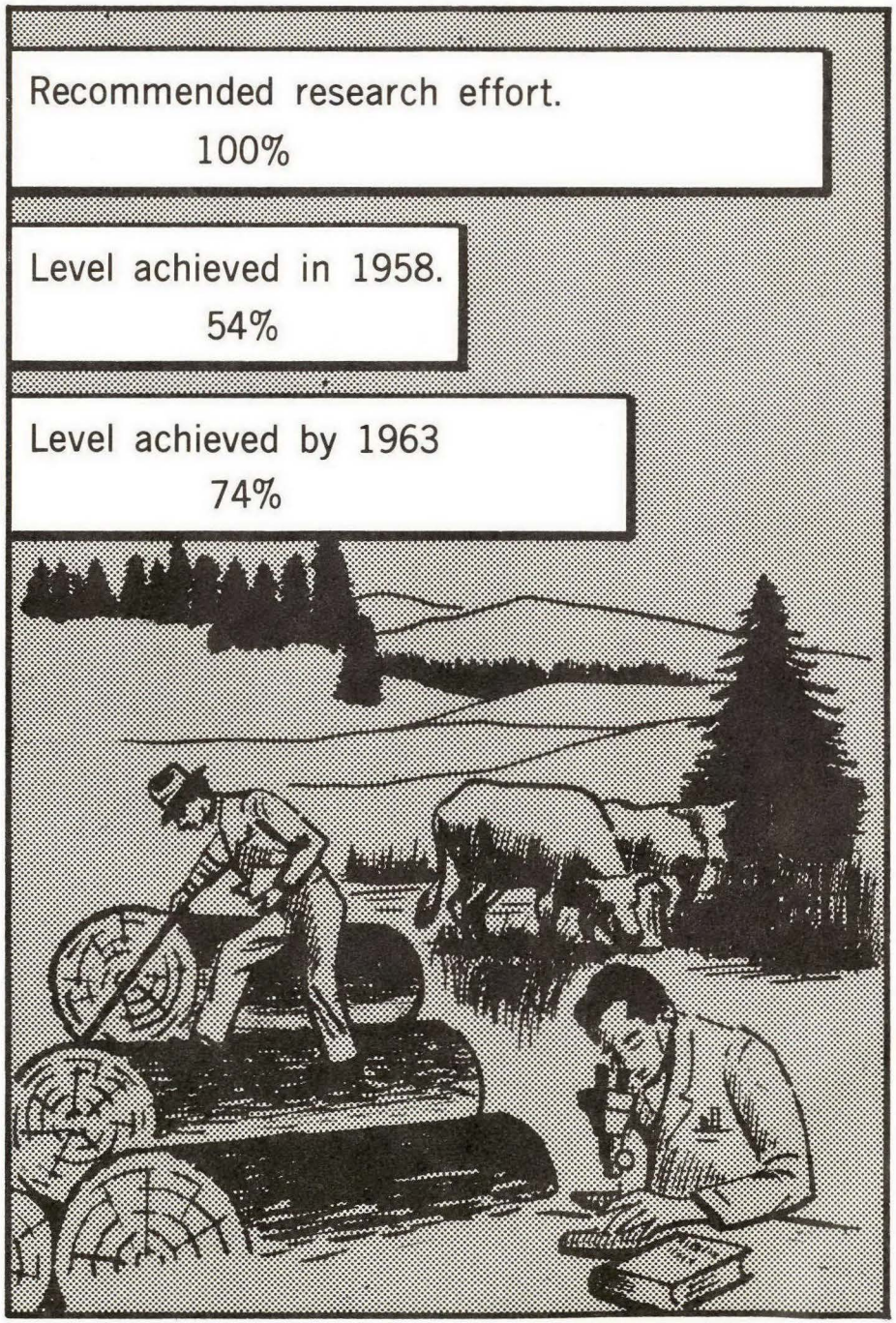

Recommended research effort.
100%
Level achieved in 1958.
54%
Level achieved by 1963
74%

Summary of Findings

Since the California Wildland Research Plan was published in 1958, the needs for wildland research have continued to grow at a substantial rate. Many of these increased needs are a reflection of the state's continuing growth in population. Others reflect unfavorable developments in the physical and economic environment. Urbanization has extended further into wildland areas, intensifying the physical problems of protecting wildlands from fire and creating economic problems in the use of land for more conventional wildland purposes. Recent developments in water policy have served to place new emphasis on increasing wildland water yields. Burgeoning recreational use has posed new problems of managing wildlands for recreation and of coordinating recreation use with other important uses. These are only examples of numerous developments which, between 1958 and 1963, have served to intensify the needs for wildland research and to modify the priorities among different lines of research.

The growth of our wildland research effort has not kept pace with these increasing needs. In 1958 the scientific manpower devoted to wildland research in California amounted to 1,713 man-months of effort per year. The 1958 California Wildland Research Plan urgently recommended an immediate increase of that effort by 1,444 additional man-months. But during the ensuing five years an increase of only 623 man-months was achieved. Thus, between 1958 and 1963, we have closed less than half the gap between research effort and the minimum needs recognized in the 1958 plan. While the problems requiring research have become even more severe, our wildland research effort is lagging.

As a first step in correcting this lag, the Wildland Research Planning Committee recommends prompt action to expand research effort to the minimum level recommended for "immediate" implementation by the 1958 Wildland Research Plan. To achieve this will require an expansion of approximately 35 percent in the 1963 level of our wildland research effort.

Trends in Wildland Problems: 1958-63

California continues to grow at a phenomenal rate. Population in 1958 was 14.7 million people; today it is about 18 million. By 1980 it is expected to be 28 million.

More people in themselves constitute a valuable resource; they bring varied talents and add to the economic and cultural strength of California. But they also cause further drain and pressures on the resources of the state. They need greater quantities of such basic necessities of life as food, fibre, water, and wood for shelter. Moreover, to ease the tensions of modern living and to spend increased leisure time profitably, they want opportunities for recreation in the great outdoors, wilderness experiences, and fishing and hunting. In terms of visits to national and state parks and forests, recreational use of California wildlands climbed from 32 million in 1957 to 52 million in 1963.

Deleterious effects may also result from population growth. For example, urban sprawl into the more accessible wildlands handicaps protection of the native vegetation from fire and pests. Cost of protection is multiplied, and damage becomes critically important. These incursions also decrease the area available for production of wood, water, and forage. Each year we need to produce more from a smaller acreage.

Admittedly, the basic problems in wildland management are more or less static in variety. This means, of course, that a simple listing of problems would show little change in a five-year period. Even in this short time, however, there has been a shift in emphasis in problems—in some cases, strikingly so—requiring revision in priorities of research.

Pest Control

A well-known example of a major development leading to a recent shift of emphasis is the general use of chemicals to control insect pests and weedy vegetation. With increasing use of pesticides, side effects have become more evident and potentially more significant. Therefore research aimed at minimizing these effects has higher priority than in 1958.

Furthermore, natural forces in recent year have not been favorable to pest control in California. Three years of record drought have weakened trees and caused a major epidemic of forest insects. Then typhoon Freida in October 1962 blew down more than 580 million board feet of timber, creating conditions for greater buildup of insect populations.

Fire Protection

In fire protection, most significant in the past five years is the fact that man-caused fires continue to be entirely too prevalent. There are some understandable reasons for this trend, but there are also some causes that cannot be explained. The priority of research on fire prevention needs to be raised because of recent events.

A continuing increase in the dying off of brush in southern California is another event of consequence in recent years. Although this change

in fuel conditions has been in progress for many years, the rate and magnitude of the change have been more rapid than expected since 1958. This change, therefore should be reflected in setting priorities and formulating the research program.

Rapid strides have been made in firefighting since 1958, especially in techniques for use of aircraft and fire retardants. Further development of these techniques holds promise of more effective forest fire control.

Both fire prevention and fire suppression have become more complicated in recent years as a result of expanding human occupancy and use of wildlands, particularly for recreation.

Utilization

In forest utilization the most significant development of the past five years has been the expansion of the wood pulp industry in northern California. This industrial development adds emphasis to the need for research on problems of pulp and paper manufacture.

California has the potential in wood and water resources to triple, at least, its wood pulp production. More pulp mills would enhance opportunities for utilization of woods and sawmill residues, for better management of young-growth timber, and for further industrial development. The realization of this potential is dependent upon finding methods for safe disposal of effluent resulting from pulp manufacture.

Markets for Forest Products

Since 1958, the postwar trend of rapidly rising lumber prices has been sharply checked. Recent market studies confirm this indication that national timber supplies are in balance with demands. Indeed, California lumber markets have shown extended periods of weakness since 1958. At the same time, in response to improved forest protection and management, forest growth continues to increase. Thus, if future forest products potentials are to be fully realized, increased attention to problems of expanding markets for such products is more urgent than before. These needs for studies of markets and market development are intensified by increased competition from wood substitutes and by the need to adjust the forest products market to changing species and size characteristics of the available wood supply.

Watershed Management

The 1963 decision of the U.S. Supreme Court on the water distribution from the Colorado River in favor of Arizona has important implications for wildland research. This decision places new emphasis

on the need for studies on the effect of wildland treatment on water yields. There is no question that the court's decision will necessitate some major planning and management changes. It is imperative, therefore, that the relationship of land management and water yield be given higher research priority than was done in 1958.

Regeneration

Interest in returning to production lands inadequately stocked with trees is steadily growing in California. Tree farming is becoming more and more the accepted practice, and the spread of intensive forestry

has revealed urgent needs for methods of seeding and planting that can succeed under the adverse conditions often found in this state. The continuing conversion of commercial forest acreage to other uses and the continuing harvest of virgin forest areas invite special attention to reforestation of the several million acres of poorly stocked lands in California.

In the past five years much has been done to show that pine forests can be successfully regenerated, particularly by planting. The success with ponderosa pine, even during the dry seasons of the past five years, tends to focus attention on the fact that many regeneration problems in the other forest types are not solved. Experimental work in seeding cut-over areas of old-growth redwood subject to windthrow has shown promise and needs careful evaluation.

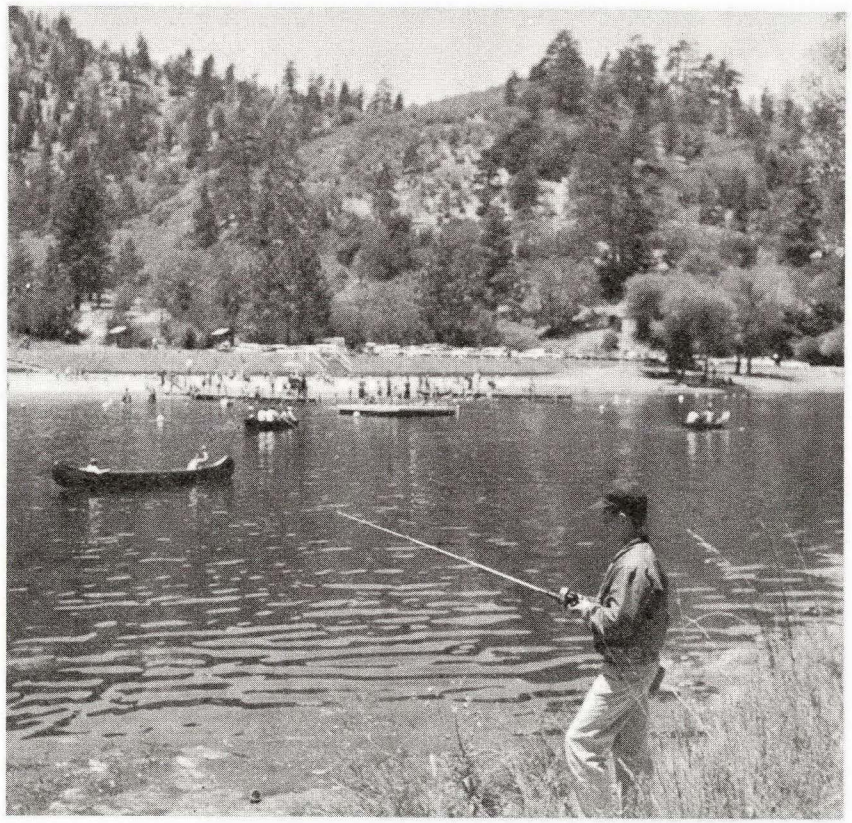
Recreation

Since 1958, outdoor recreation planning has been given strong impetus at both state and national levels. The California Public Outdoor Recreation Plan published in 1960, was followed, in 1962, by the various reports to the President and the Congress by the Outdoor Recreation Resources Review Commission. These reports define the growing problems of wildland recreation and project much greater recreational use of wildlands in the years ahead. They emphasize the urgent need for greater effort in research pointed at all aspects of wildland recreation.

In addition, growing recreation use has complicated both the management and the economics of using wildlands for other purposes such as timber growing and forage production. A number of these interactions between recreation and other land uses are in urgent need of study.

Range Management

The livestock industry in California has long been engaged in the job of reclaiming wildlands for forage production—converting acres of brush or trees to grass. This conversion job is being done with increasing attention toward subsequent management of the range resource. There is more need for information on site selection and on followup measures to improve the converted area. Additional research is needed and should be aimed at improving methods of managing wildlands for use by livestock and game.



These are but highlights of major changes since 1958. Other factors not mentioned here have had to be considered, too, and are reflected in this revised Wildland Research Plan for California. Local differences in the economy and environment may suggest differences in outlook but this analysis must present a statewide view.

The following sections highlight the progress in wildland research since 1958 and make recommendations of current research needs to help achieve a coordinated effort in the years ahead.

Some Examples of Research Progress and Findings: 1958 to 1963*

On Forest Fire . . .

- Tests of cloud seeding of thunderstorms showed that seeding from the ground cannot significantly increase rainfall or decrease lightning potential.
- A fire danger rating system for California was devised and installed.
- A system of 10-day fire weather reports was developed and installed.

- Fire climate studies added knowledge about the nature of local weather, such as marine air flow and wind shifts, and its effect on fire behavior.
- Use of viscous water in tank trucks was developed and applied.
- Four new fire-retardant chemicals for use in air tankers were developed and applied.
- A variety of studies were made on methods of fuel hazard reduction, including use of fuel-breaks, slash disposal, and prescribed burning.
- Intensive studies were begun on attitudes of forest users in relation to fire prevention.
- Fundamental research was started on the chemistry of the combustion process.

On Forest Insects . . .

- New methods (including radiographic techniques) have been developed to provide accurate methods of estimating bark beetle populations.
- Oleoresin pressure, the effects of resin on insects, and the attraction mechanisms of trees and insects were shown to influence the success of bark beetle attacks on pines; sex attractants of certain bark beetles have been isolated and show promise of providing a new basis for control.
- Removal of highly susceptible trees from old-growth pine stands was shown to have longer lasting effects on the damage from bark beetle attack than was previously thought.

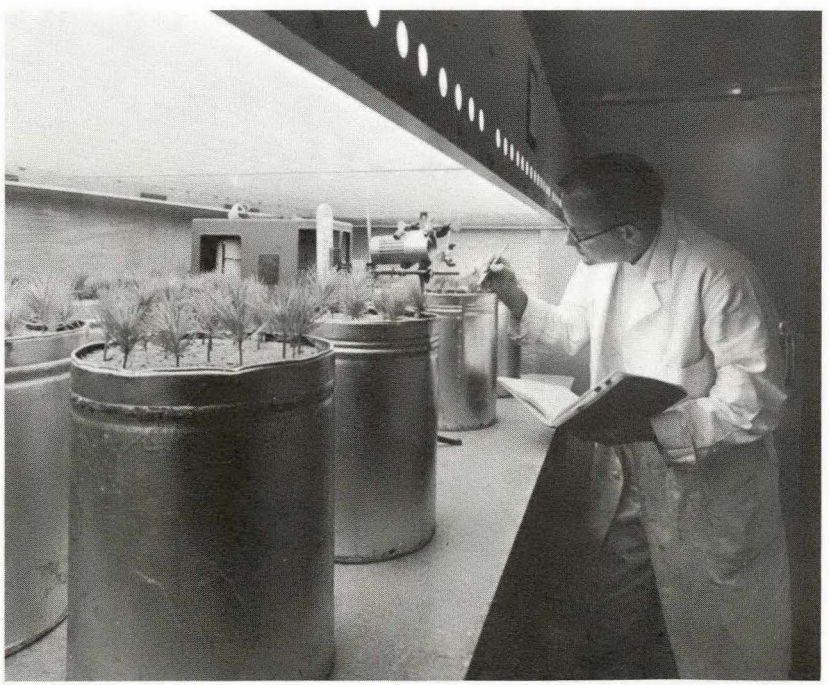
* A complete statement of research progress would require a detailed list of specific research findings and work in progress. Such details are given in a supplement to this report (available from the State Forester). It is the nature of science that many accomplishments of recent years are not yet ripe for evaluation. The examples of research progress given here suggest progress in the past five years, but the total result of this research effort cannot be known until the future provides additional perspective.

- Insecticides for use against bark beetles and lodgepole needle miners have been formulated, screened, and tested, resulting in the first practical method of controlling the needle miner and in halving the cost of spraying for bark beetles.

- Basic knowledge was gathered on the biology and damage characteristics of several insects that reduce seed crops in conifers.

On Forest Diseases . . .

- Root diseases were found to be the cause of severe losses in forest nurseries; sanitation measures prescribed to combat these diseases reduced the amount of seed required, reduced cost of weed control, and produced better seedlings.
- Host-specific forms of mistletoe were identified, leading to new recommendations for the management of infested fir stands.
- Smog was identified as an important cause of X-disease in southern California forest trees; identification of apparently smog-resistant trees has provided a basis for developing smog-resistant planting stock.



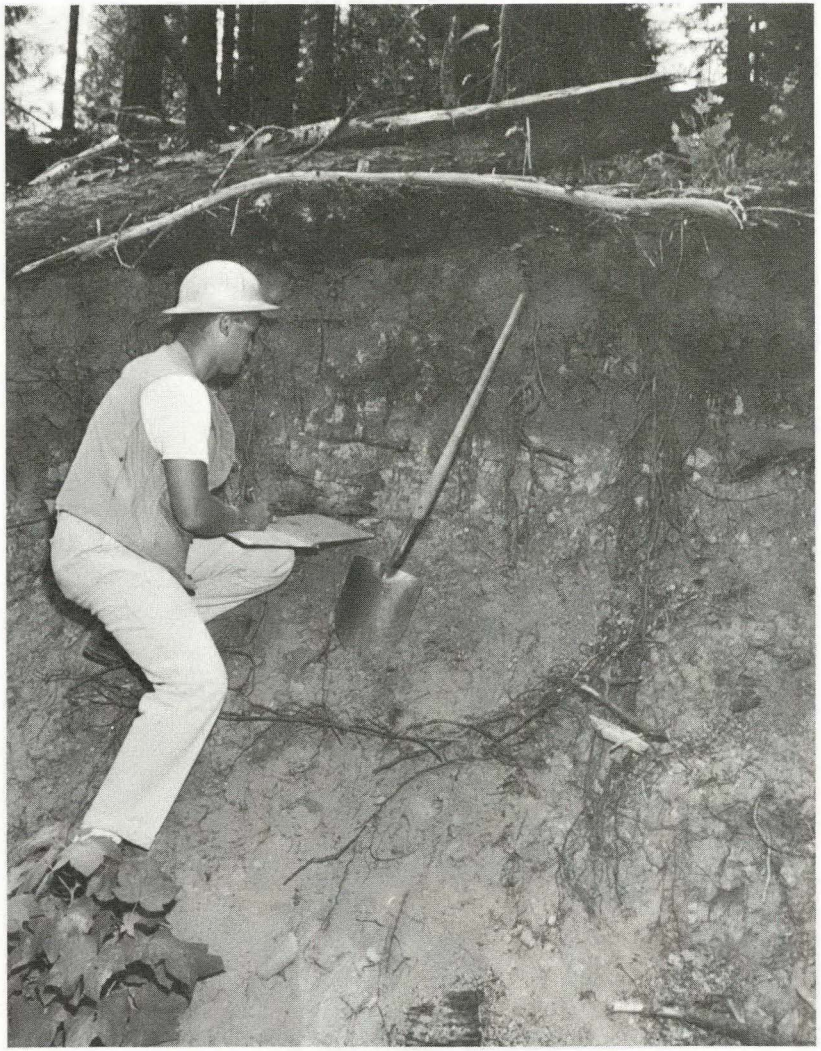
- Guidelines were developed to help foresters estimate probability of survival of fire-damaged trees.

On Wildland Soils . . .

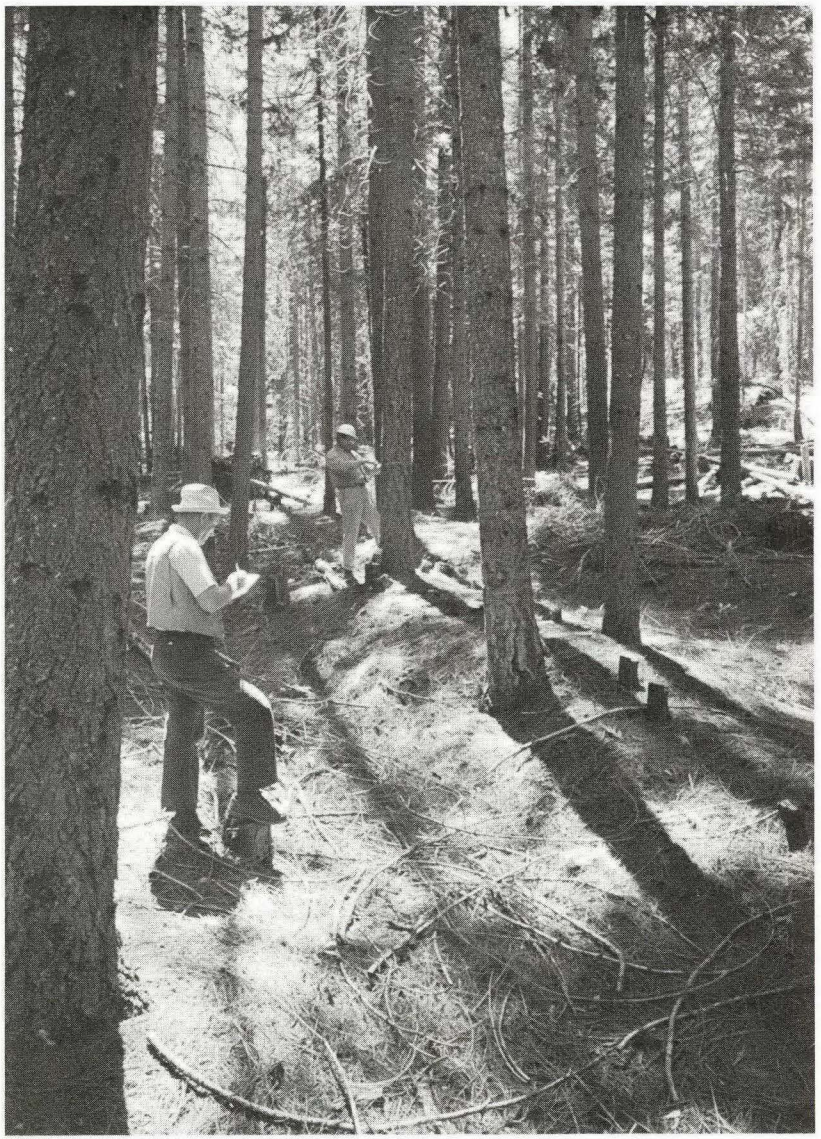
- Soil vegetation surveys were completed on approximately 2.7 million acres of wildland. Soil vegetation maps were published for 109 quadrangles.
- The relationships between nitrogen content, wildland soil type, associated vegetation, and site fertility were determined.
- Nitrogen balances of soil and vegetation in chaparral- and forest-covered lysimeters were reported.
- The influence of a forest stand on the soil-moisture regime of a large lysimeter in southern California was reported.

On Timber Growing and Harvesting . . .

- A comprehensive study of geographic variation in knobcone pine was completed, and breeding orchards for the outstanding Monterey × knobcone hybrid were established.
- Resistance of the hybrid Jeffrey × Jeffrey-Coulter pine to pine reproduction weevil and to three important native bark beetles was demonstrated.
- Developmental research on seed and hybrid production provided considerable experience in applying genetics research knowledge to tree improvement practice.
- Results of studies of seedling physiology and root regeneration have led to modification of nursery practices and planting procedures which have improved survival of planted trees.
- Results of studies of Douglas fir and redwood seed production and dispersal provided information essential for effective management of these types; aerial seeding of Douglas fir was demonstrated to be a successful means of regeneration on some sites; results of microsite studies in pine, Douglas fir, and redwood permit more effective use of natural seed sources.
- Effects of thinning, weeding, and pruning on quality and volume of growth of forest stands have been determined and guides to stand improvement practices prepared.
- Empirical yield tables and 10-year growth predicting equations for young-growth redwood have been published and similar material for young-growth ponderosa pine is nearing completion.



- Influence of logging methods on production, costs, and damage to residual stands has been analyzed for three important forest conditions.

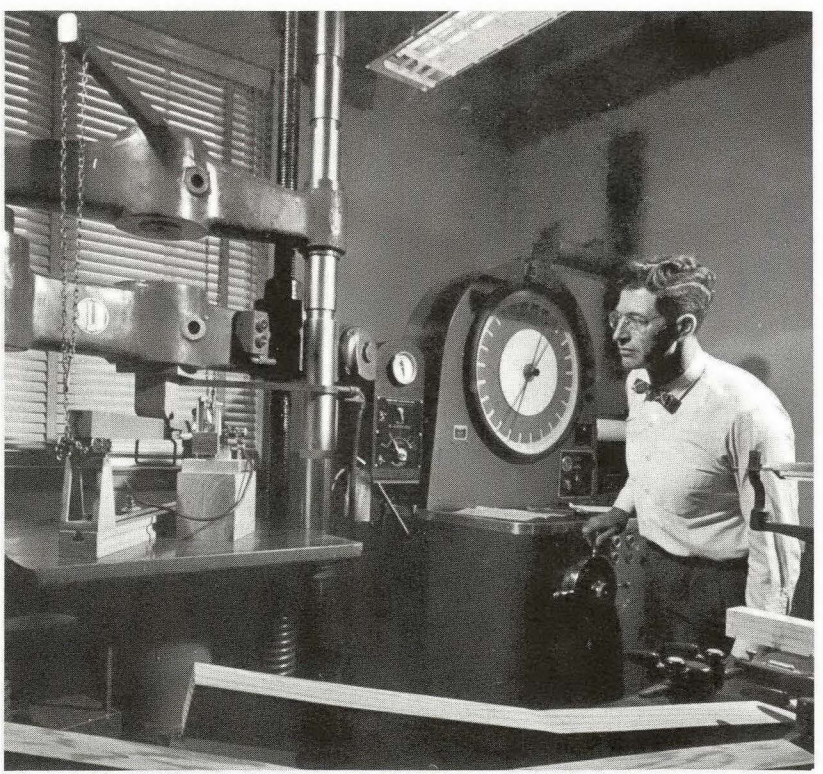


On Forest Products . . .

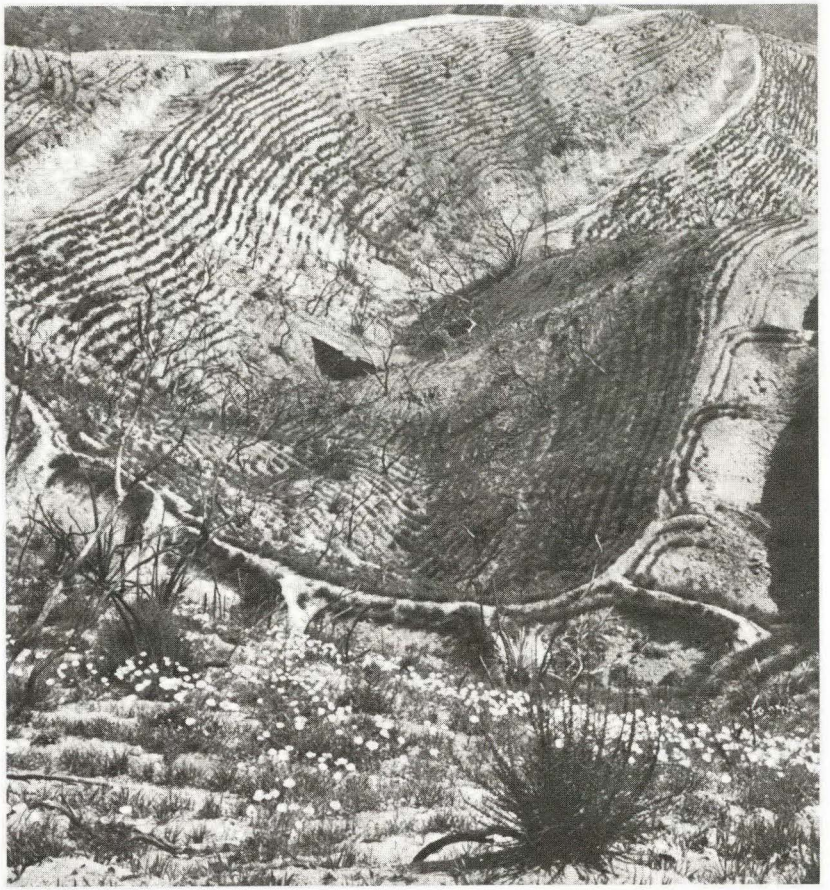
- New drying procedures have been developed and applied for several California hardwoods and for redwood.
- The extractive compound causing most of the black stain in redwood lumber has been isolated, and drying procedures designed to minimize such stain have been suggested.
- Physical properties of some principal California hardwoods have been determined.
- White fir and redwood have been successfully pulped in the laboratory by a modified nitric acid process whose effluent provides a potential commercial fertilizer.

On Range Management . . .

- The Sierra Foothill Range field station for research on management of beef cattle ranges was established; cattlegrazing research at the San Joaquin Experimental Range made progress in the formulation of range management systems for natural and fertilized annual plant ranges.



- A rest-rotation range management system has been shown to be effective during drought.
- A practical guide to bitterbrush seeding on eastside deer winter ranges, reflecting 10 years of research, was prepared for publication.
- A variety of grass called "Mission" veldtgrass was developed and certified, providing a good seed producer at reasonable cost suited for range, wildland, and beach plantings for forage use and erosion control in southern California.
- Changes in vegetative composition and productivity were measured over a seven-year period on ranges converted from brush to grassland.



On Watershed Management . . .

- It was demonstrated that conversion of brush to grass saved water in southern California soils more than 30 inches deep if annual rainfall is sufficient to penetrate below the grass roots; but if weeds enter the grass cover, water losses equal those under native brush.
- Treatment of burned watersheds by such practices as establishing rows of barley at two-foot intervals or by properly engineered contour trenching reduced storm-caused erosion by 36 to 68 percent.
- Analysis of terrain, shade, and shelter effects in forests, provided foresters some suggestions as to the best size, shape, and orientation

of forest openings to increase accumulation and delay melting of snow.

- On selected watersheds effects of type of logging on streamflow and sedimentation were measured and analyzed.
- Instrumentation and techniques for watershed research were improved by invention or perfection of a variety of new pieces of equipment and methods of use.

On Wildland Recreation . . .

- The effects of short-term and long-term human use on vegetative cover were surveyed in several situations in Yosemite Park, Sequoia and Kings Canyon Parks, and Humboldt Redwoods.
- A comprehensive report on wilderness areas in their national perspective was published.
- The potential impact of recreation development on timber production was assessed for three national forests in the state.
- Criteria were designed and published to help professional foresters recognize decayed trees which are dangerous to campers or other recreationists.

On Wildland Economics Research . . .

- An analysis of young-growth timber taxation in Mendocino County suggesting conclusions as to timber tax policy and administration was made and published in cooperation with concerned agencies.
- An analysis of marketing practices affecting small woodland owners was completed and published for two major forest regions of the state.
- Surveys and publications were continued dealing with forest industry production, timber inventory, and logging residues.
- Continuing study was devoted to the economics of wildland fire protection.
- A study was virtually completed analyzing the economic development prospects for commercial forest resources and forest products industries of the state.

Level of Research Effort on Wildland Problems

These examples give some idea of the scope and diversity of wildland research from 1958 to 1963. If the reader bears in mind the difficulties of quantifying or even summarizing such a broadly ranging program, one useful integrated measure of overall progress is provided by estimates of scientific manpower devoted to wildland research projects. In 1958, such manpower totaled 1,713 man-months, according to the best available estimates. By 1963 the total had risen to 2,336 man-months. Thus, between 1958 and 1963 research effort increased by 623 man-months.

Table 1. SCIENTIFIC MANPOWER NEEDED AND DEVOTED TO WILDLAND RESEARCH IN CALIFORNIA: 1958 AND 1963 [1]

Research area	*Recommended 1958 manpower goal (1)* Man-months	*Actual manpower in 1958 (2)* Man-months	*Proportion of goal achieved in 1958 (3)* Percent	*Actual manpower in 1963 (4)* Man-months	*Proportion of 1958 goal achieved in 1963 (5)* Percent
1. Forest fire	488	224	46	391	80
2. Forest insects	307	187	61	216	70
3. Forest disease	189	99	52	108	57
4. Soils	329	173	53	201	61
5. Timber growing and harvesting	422	182	43	286	68
6. Forest products	186	86	46	145	77
7. Range management	447	345	77	407	91
8. Watershed management	354	174	49	250	71
9. Recreation	139	103	74	112	81
10. Economics	296	140	47	220	74
Total	3,157	1,713	54	2,336	74

[1] Includes programs of the Pacific Southwest Forest and Range Experiment Station, University of California Agricultural Experiment Station, California Division of Forestry, and U. S. Forest Service, Region 5.

This increase in effort may best be evaluated by comparing it with the 1958 recommendations of the Wildland Research Planning Committee. The committee recommended then an immediate goal of 3,157 man-months of scientific manpower. This represented an expansion of 1,444 man-months to meet high priority wildland research needs. Five years later, the actual increase had amounted to less than 45 percent of the recommended goal.

The information on manpower goals and current and past research effort has been classified by broad problem areas in Table I. Comparison of figures in column 3 with those of column 5 shows that in some research areas—such as forest fire and forest products—the amount of progress has been substantial even though the effort still falls well short of the goals set in 1958. In other research areas—such as insect and disease problems, soils research, and recreation—we are doing only slightly more research now than we were five years ago. Yet those areas include problems which have increased dramatically in their importance during the same period.

In aggregate the research expansion achieved since 1958 has been discouragingly small in relation to the needs recognized in the Wildland Research Plan. After five years of effort we have achieved considerably less than half of the research expansion recognized as having high priority in 1958. In view of the additional problems and needs which have emerged since that date, we appear to be little better off than we were five years ago, in terms of the adequacy of research effort to meet current urgent requirements.

Needed Additional Research

To appraise the extent and direction of changes in wildland research needs since 1958, specialists in each of the major research areas were asked to revise the statements of the needs which were published in the earlier *Plan*. These revised lists of research needs are given in the pages which follow.

FOREST FIRE RESEARCH

A. *Fire Prevention*

Fire prevention research studies the nature, cause and possibilities of eliminating fire-starting sources of all kinds. Needed are:

Studies into the social, economic, moral, and psychological characteristics of people who cause forest fires.

Yardsticks to measure the success or failure of prevention programs and determine the psychological effects of law enforcement and prevention efforts.

Basic studies in the classification of fire causes and attack on the difficult problem of preventing fires started by children playing with matches.

Studies aimed at gaining a better understanding of the atmospheric factors influencing the occurrence, behavior and control of lightning.

Tests to determine the feasibility of preventing or reducing lightning fires through cloud modification.

Studies of the correlation of lightning fires with weather bureau radar observations and better methods of predicting lightning associations with weather patterns.

B. *Fire Control*

Fire control research is made up of four main subjects—detection of fires, prediction of fire behavior, attack systems, and fire suppression techniques and equipment. Detection research should include:

Studies of remote-control networks, fixed and mobile infrared detectors, and other possible systems of finding fires.

Evaluation of aircraft for detection to determine costs and applicability for both independent observations and searches as a supplement to conventional ground systems.

Behavior prediction needs are:

Measurements of rate and direction of fire spread and the intensity of burning for various weather, topographic and fuel conditions.

Development and evaluation of fire danger rating systems.

Fireclimate surveys to determine local wind patterns.

Development of prediction techniques for critical burning conditions of low fuel moisture and high winds.

For attack systems:

Systematic analysis of the proper size and type of forces to be used against various fire situations.

Development of dispatch decision guides and procedures, including use of fire command simulators.

Techniques and equipment studies should provide for:

Design and testing of new tools and materials for the suppression of fires and for control by means of chemicals that retard or accelerate combustion.

Operational techniques for such recent aids to firefighting as the helicopter, the air tanker and chemical fire retardant.

Devices for fire control training.

Fundamental research on the physics and chemistry of combustion should be expanded.

C. *Fire Use*

The possibilities of using fire to aid in the care and management of wildland crops have been explored on a limited scale. The research effort should be strengthened to include:

Prescribed burning studies to develop practical techniques for executing safe and effective burns; much more information is needed on this practice and on the effects of fire and heat on soils and vegetation.

Studies of the most desirable form and composition of vegetative cover for various purposes, and how this combination may be economically achieved through the use of fire.

D. *Reduction of Native Fuel Hazard*

California has two major types of hazardous native fuel situations. They are (1) chaparral and (2) timber slash on cutover lands. Studies must include:

The development, testing, and evaluation of ways and means of breaking up or otherwise modifying expanses of chaparral brush to facilitate fire control. These studies should include physical, chemical, and biological approaches to the problem, including investigations of "green belts," dwarf species of low profile, and plants low in flammability and fuel volume.

In timber slash, studies are needed to determine how to reduce the potential for large and destructive wild fires by selective fuel hazard reduction and modification of forest management practices.

In addition, there is a need to find ways to reduce or eliminate fuel hazards along roadsides and right-of-way.

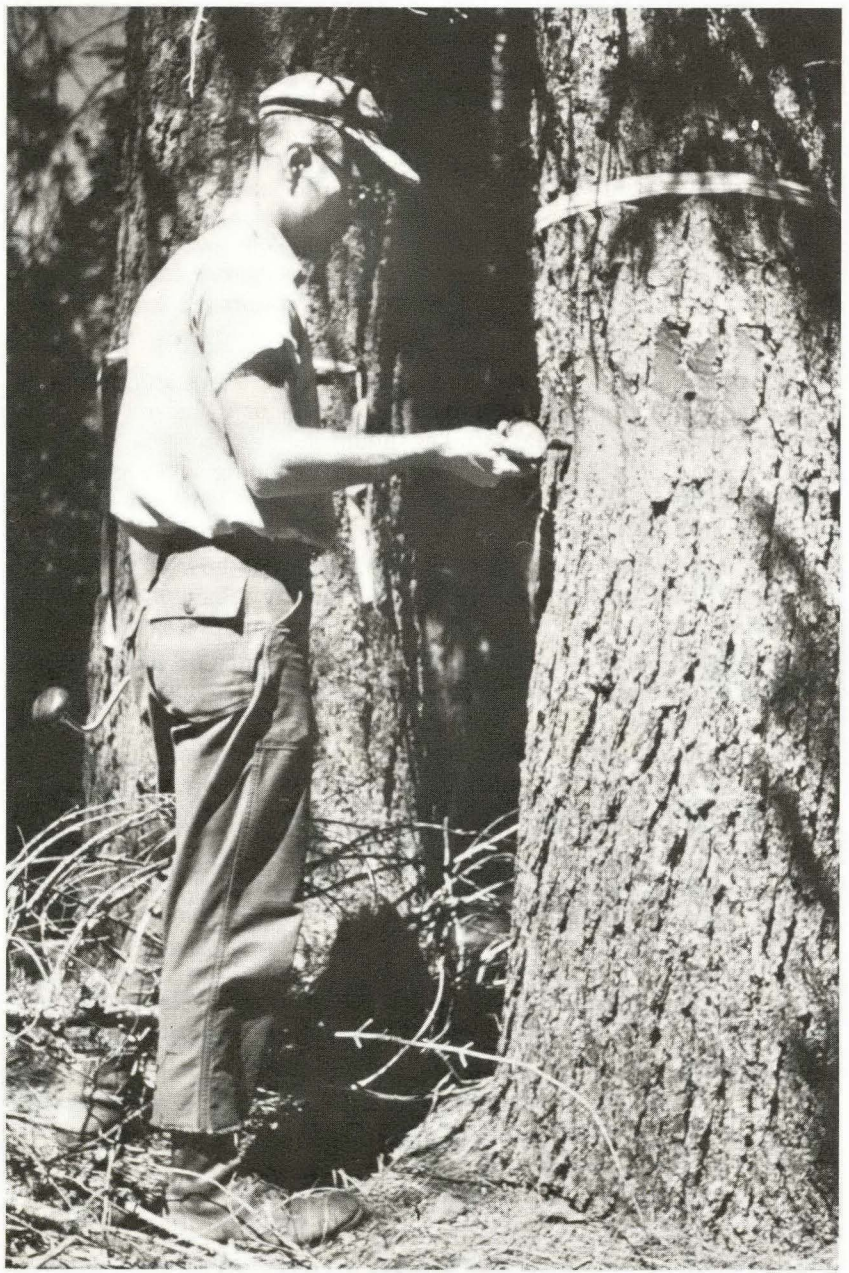
E. *Fire Economics*

Economic analyses guide fire suppression decisions, help evaluate alternate means for attaining stated physical goals, and help set fire protection goals. Because valuation concepts are inadequate and physical data limited, concentration of research on production relationships appears desirable. Needed studies are:

Define and measure the physical output or "products" of protection activities. This essential first step will require the development of an adequate probabilistic model for forecasting the physical results of various protection practices.

Determine the costs, in economic terms, of such practices as fuel modification, varying degrees of suppression readiness, or new techniques in direct control.

Develop economic guides for fire damage appraisal, and explore the possible existence of economic benefits from fire protection in addition to reduction of direct fire damage.



FOREST INSECT RESEARCH

A. *Surveys*

1. Detection and Appraisal Surveys. Surveys detect outbreaks of native or introduced insects in their early stages and make it possible to appraise insect-caused damage and the destructive potential of threatening infestations. Needed are:

Continuous inventory of the drain on forest resources from insects.

Development of information to supplement biological and ecological studies (e.g., damage potential, distribution, hosts).

Studies to improve survey methods, including the development of precise sampling techniques for obtaining quantitative estimates of insect populations.

2. Taxonomic Studies and Faunistic Surveys. Such research forms the foundation for other lines of entomological study. It should include:

Taxonomic studies to define the insect species to be dealt with, reveal the characters by which each may be recognized, produce keys for separating species, and show relationships useful in other insect research.

Faunistic surveys to determine distribution of insect species in the state.

B. *Basic Studies*

1. Biological Studies. Research on insect biology provides information essential to reduction of damage—how an insect pest exists, how it causes damage, where in its life cycle it is most likely to be vulnerable, what control measures may be successful, and when they should be applied. The needs are:

Studies of the life history and habits of insects, including studies of life stages, their occurrence, location and duration.

Studies of range, host plants, and part of plant affected.

Studies of the character of insect work and its general effect on the host.

2. Ecological Studies. Ecological studies look into the environmental factors that affect the behavior of insects and insect populations. They shed light on the underlying causes of outbreaks, show when they may be developing and how they may be prevented. Knowledge of this type is necessary to the development of more effective silvicultural control. Needed are:

Studies of the reaction of individual insects to their environment.

Studies of the dynamics of population buildup, including factors regulating populations, such as host plants, competition, or other biological organisms, the degree of artificial regulation needed for effective control, and the effects of microorganisms and climate on host environment.

Investigations of host resistance mechanisms, and the effect of insects on host resistance or susceptibility.

3. Physiological and Nutritional Studies. Research on the physiological requirements of insects for food and moisture helps explain such phenomena as host specificity, variation in individual tree susceptibility, and variability in development of insect broods. It is required for perfecting any type of control measure, and is of value in certain types of population surveys. Studies should include:

Insect responses to stimuli from odors, tastes, and moisture associated with the host.

The role of microorganisms in relation to insects' responses and nutritional needs.

C. *Control*

1. Chemical Control. Investigations of chemicals for controlling bark beetles and other forest insects provide information needed to perfect more effective, cheaper, and safer means of using chemicals in combating destructive insect pests. Chemical control research should include:

Studies to establish toxicity indices of residual insecticides and the factors that influence their effectiveness; these studies should identify those chemicals which adequately control pest numbers with minimum side effects, should develop the safest, most economical methods of application, and should determine the factors that influence the effectiveness of residual sprays.

Study of the development of resistance to insecticides in bark beetle populations.

Studies of the potentialities of systemic insecticides.

Studies to improve and develop methods of applying chemicals for protecting forest trees and wood products from insect attack.

Studies of the long-term effects of large-scale chemical control on the insect and its environment, including effects on the ecological community.

The importance of coordinating this research with research on chemical side effects is fully recognized and all agencies concerned with this problem are urged to insure that such coordination is achieved.

2. Biological Control. Research on biological control looks into the natural enemies, both disease and other insects, that attack forest insect pests to determine the possibilities of using these natural enemies as control agents. It can also be considered to include research on insect sterilization techniques, artificial or natural attractants, and other biological approaches to the regulation of pest populations. These control studies should include:

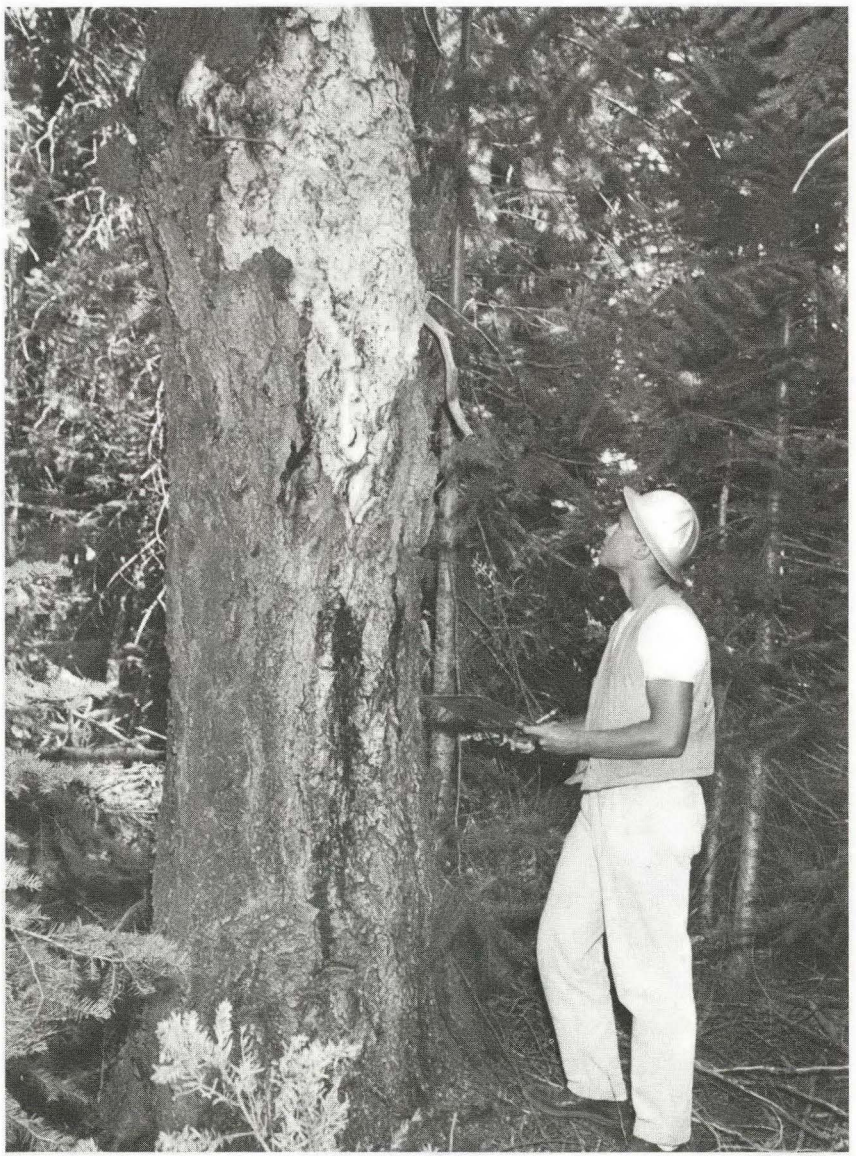
Surveys to determine the kinds and abundance of the enemies of major pests and to evaluate their effectiveness.

Studies to develop methods of fostering specific natural control agents found to be promising and field tests of these agents.

Importation of natural enemies of foreign origin.

The possibilities of biological agents for controlling most forest pests are largely unknown although viruses have checked some forest defoliators. These studies should fill this gap and perhaps provide potent new control methods for some major pests.

3. Silvicultural Control. Silvicultural control studies seek to develop methods of preventing or minimizing insect damage through forest management practices such as sanitation-salvage operations or timely logging of windthrown, lightning-struck, and fire-injured trees. To show the extent to which silvicultural methods can be relied upon, studies in various forest types should:



Establish criteria for recognizing trees most susceptible to insect attack.

Determine the relation of logging slash to insect damage.

Investigate the way different silvicultural and management practices influence insect problems.

Test these practices to determine how they may be used most effectively for insect control.

FOREST DISEASE RESEARCH

A. *Detection and Appraisal Surveys*

Disease surveys provide for early recognition of, and action on potentially dangerous tree diseases in the several forest types of California. Information gathered in this work not only aids in planning control, but also points to research needs. The work should include:

Qualitative and quantitative on-the-ground inspections of diseases reported by state, private, and federal cooperators and on statewide sample plots.

Studies to improve survey methods and to accelerate compilation of data showing the drain on forest resources from diseases.

B. *Basic Studies*

1. Mycological and Taxonomic Studies. Effective damage appraisals, field research, and control methods depend on the accuracy with which diseases with similar symptoms can be distinguished. To provide this information mycological and taxonomic studies should:

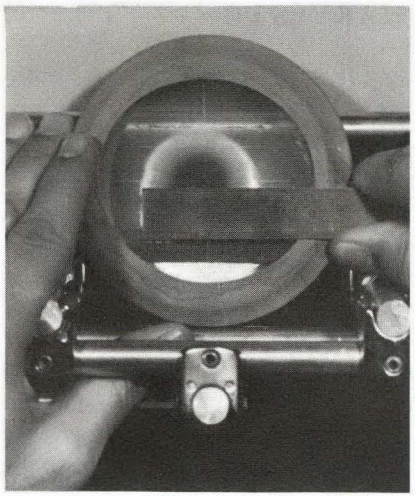
Identify the organisms responsible for forest disease.

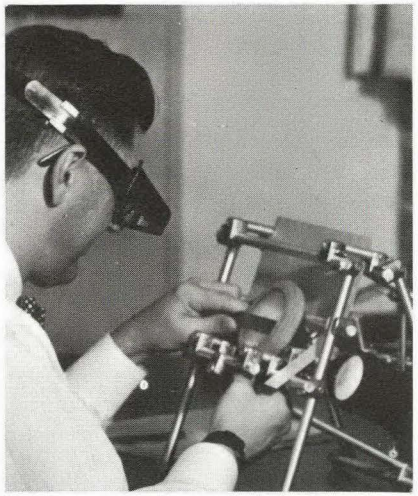
Develop methods of distinguishing these pathogens. Work out their life cycle and interrelationships.

2. Ecological, Environmental, and Host-parasite Studies. This research makes it possible to identify vulnerable stages of disease development, so they can be attacked by silvicultural manipulation, by elimination of predisposing factors, or by direct biological or chemical controls. Such research must:

Study the sequence of events in the life of the pathogen and of the host plant which leads to disease development.

Learn how the environment modifies or affects this sequence of events and how the host, pathogen, and environment interact.





Pin down information on spore (or seed) production, dissemination, germination, and penetration of the host; the conditions which predispose the host to infection; the changes in metabolism and structure of the host which result in damaging symptoms; the defense mechanisms of the host; and the influence of environment on these stages of disease development.

3. Noninfectious Diseases. These include tree damage from such adverse environmental factors as frost, ice, snow, heat, drought, wind, or air pollutants. The research program should:

Develop methods of diagnosing noninfectious diseases.

Define the criteria by which hazardous sites can be recognized and by which damaged stands can be salvaged.

Determine the means by which damage may be minimized through changes in management practices.

C. *Control*

1. Chemical and Biological Control. These studies directly aid going control jobs and suggest new and improved methods to reduce damage from forest trees diseases. Needs include:

Studies on the use of contact and systemic herbicides and fungicides for the control of host plants and of disease organisms in the tree or soil.

Surveys to determine the kinds and abundance of competitive organisms that might control major pests.

Location, selection, and testing of disease-resistant tree species.

2. Silvicultural Control. Many diseases are expensive or impractical to eradicate but might be reduced to the status of a minor pest by sound silvicultural methods. Silvicultural control studies should:

Test the usefulness and costs of preventing or minimizing disease losses through managerial practices, such as sanitation logging, pruning, slash disposal, thinning, prescribed burning, and species alternation.

Develop criteria for appraising the probable impact of diseases on management and protection work in various forest sites.

Establish demonstration areas to aid in application of research findings.

WILDLAND SOILS RESEARCH

Investigations into kinds of soils and vegetation, their relationships, and their distribution provide a powerful management tool. Most wildland management decisions depend on such knowledge, and it is fundamental for much other research. Needed are:

Characterization, classification, and mapping of soils and vegetation. This program should determine standard physical, chemical, and morphological characteristics of soils and the composition and density of vegetation and characteristics of timber stands. The work should include standard tests of soil fertility, determination of timber site index, and appraisal of the erodibility, moisture-holding capacity, and permeability of different soils. It would provide estimates of suitability for various uses—particularly for timber production and range forage production under extensive management. And it would show the general mechanical characteristics of different soils that affect road construction.

Studies of the effect of management practices on soil properties and soil behavior. The research should explain changes in soil brought about by management for timber, forage, or other products and how these changes affect subsequent management of the soil for the desired or alternate uses.

Studies concerning soil manipulation practices useful in wildland management. To develop techniques that will improve the productivity of California soils—whatever the objective of the wildland manager—studies of soil manipulation should include fertilization methods, soil and site preparation procedures for various purposes (such as

achieving forest regeneration or range reseeding), and practices needed to obtain certain engineering objectives, such as construction of road fills or stabilization of side slopes. These soil manipulation procedures must be specific for certain categories of soils.

TIMBER GROWING AND HARVESTING RESEARCH

A. *Forest Tree Improvement*

Forest tree improvement research is concerned with propagation of trees that are superior in terms of tree form, wood quality, pest resistance, or other desirable characteristics. Needed research includes:

Genetic studies to determine (a) the nature and extent of variation in form and function within species; (b) the inheritance of characters; (c) what species can be crossed and the character of hybrids produced. Major emphasis on the genetics of pines should continue. Expansion of efforts to improve other important genera is also needed.

Physiological and biochemical studies to determine the basic factors that affect or control the processes associated with flowering and sexual reproduction in trees, and asexual reproduction in trees through rooting of shoots. Such information is needed to enable tree improvement workers to bring young trees of many species into vigorous reproductive activity and to cause them to flower and reproduce regularly and abundantly. This should, in turn, speed up genetic research and breeding and the practical application of the products of breeding.

B. *Improved Seedling Establishment*

Natural regeneration studies are an important phase of reforestation research. These should include determination of:

Habitat conditions required for successful germination, survival, and growth of all commercially important timber species.

Methods for eradication of brush cover by use of machines, chemicals, and fire.

How to induce more abundant seed crops.

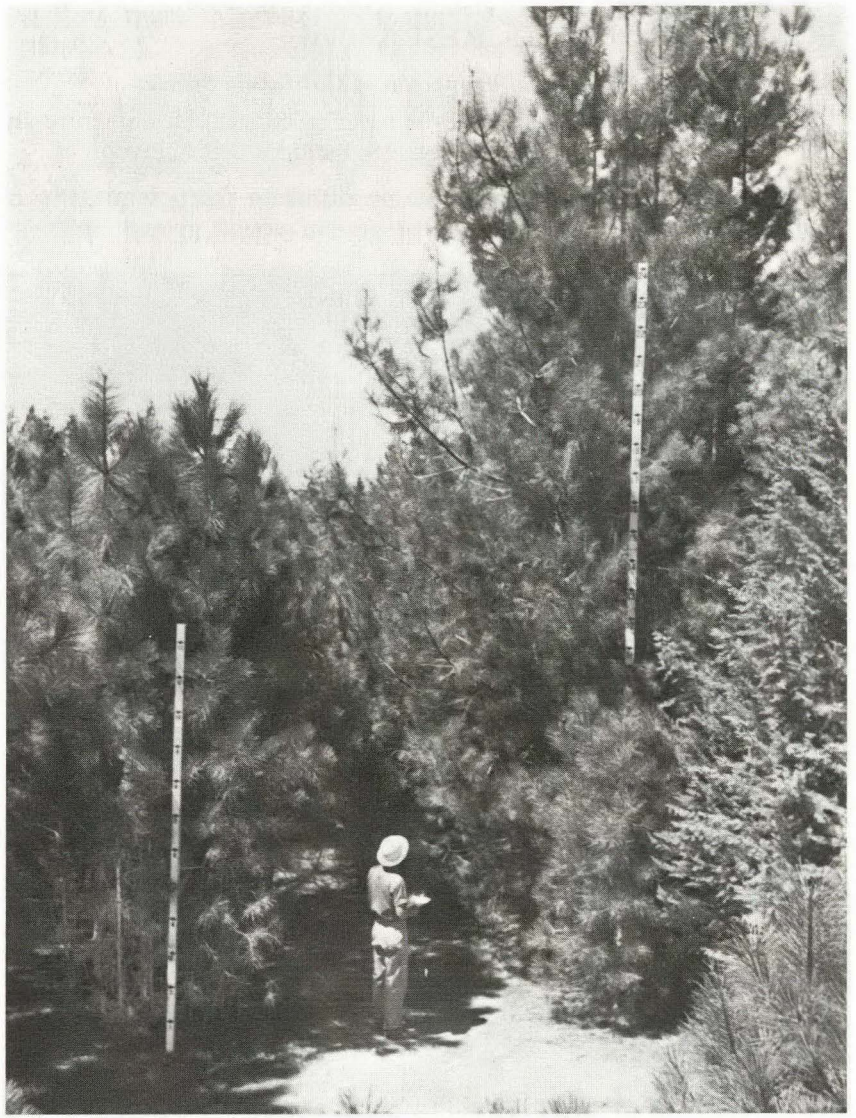
How to reduce destruction of seeds by seed-eating rodents and other animals.

Effective direct-seeding techniques which could materially hasten the rehabilitation of deforested land are an urgent need. Direct-seeding studies should include research to learn:

The physiology of seed ripening and the requirement for effective storage and germination of tree seeds.

The best sources of seed to plant in different localities.

How to prevent damage by rodents to planted seed.



A third part of this program should improve production of planting stock and subsequent field planting. These studies should determine:

The best psysiological condition of nursery-propagated trees at the time of field planting.

The optimum spacing of trees and soil fertilization in nurseries.

Specifications for desirable planting stock.

How to eradicate undesirable vegetation from planting sites.

How to prevent injury to planted trees by animals, especially porcupines and deer.

The possibilities of soil fertilization in young plantations to stimulate early growth, enabling conifers to compete more favorably with other vegetation and to outgrow deer damage faster.

C. *Manipulation of Growing Stock*

For all major forest types, studies are needed to attain high production in volume and quality and to indicate the physical means and financial feasibility of accomplishing such production. This research should:

Define desirable levels of stocking at given ages, from initial regeneration to final thinning or harvest cutting, to achieve various product and financial objectives.

Develop definitive physical and economic input-output information for quality improvement practices to control knot and defect content, diameter growth rate, fiber length, and wood density.

D. *Prediction of Growth and Yield*

Allowable cut and multiple use have emerged as major problem areas which require better projections of growth and yield. Conversion of old-growth forests, often by partial cutting, raises the need for gaging the growth potential under various levels of reserve stand, as compared with the potential under clear-cutting and prompt reforestation. Where other users become competitive with timber growing, a surer knowledge of growth potential foregone would sharpen comparisons of management alternatives. Research must:

Develop techniques for accurately forecasting timber growth and yield in both residual old growth and young timber stands, whether essentially pure or of mixed species.

Define usable site classifications so that yield tables can be compiled. Site, growth, and yield data are essential tools used to decide forest land management policies.

E. *Methods of Timber Harvesting*

Timber harvesting studies must continue to search for better techniques of planning harvesting processes to reduce costs and to preserve the productivity of the soil and residual stands. They must:

Compare the performance of various types of equipment as related to silvicultural-management requirements in both old growth and young growth stands.

Explore the feasibility of using more highly mechanized and automated equipment for thinning and harvesting operations to keep the industry abreast of national trends of increasing productivity.

Seek the means to improve workers' physiological, physical, and mental efficiency in combination with the machines they use.

Develop and test systems for controlling the arrangement of growing stock to meet the needs of increased mechanization in growing and harvesting.

Determine methods of controlling and manipulating forest stands to provide maximum esthetic values for various recreational uses.

FOREST PRODUCTS RESEARCH

A. *Physical and Mechanical Properties of California Species*

Knowledge of wood properties is basic to efficient manufacture and use of timber products. Needed research includes determination of:

Standard strength data and data on shrinkage for potentially commercial hardwood species and for certain young growth softwood

species. Means to improve joint strength—nailed, screwed, bolted, and glued. An understanding of the movement of gases and liquids in wood.

The relationship of anatomy and physical properties of wood to the weathering of wood.

Rheological properties and surface properties.

Microproperties of wood and the relation of these to macroproperties.

B. *Wood Chemistry*

Research in wood chemistry can develop new products or processes needed to approach the goal of full use of available timber. Studies should:

Isolate and identify naturally occurring organic compounds, and relate their characteristics to certain properties and features unique to the tree species.

Determine potential economic uses of these extractives, and of chemicals from lignin and cellulose derivatives.

C. *Wood Fiber and Wood Particle Products*

Industrial expansion based on use of wood in the form of fibers and small particles is relatively new in California. To encourage this expansion, the needs are:

Wood fiber research to develop manufacturing methods suitable for California species that will produce fiber having desirable properties for paper and/or other fiber products, high-quality cellulose, and economically usable process residuals.

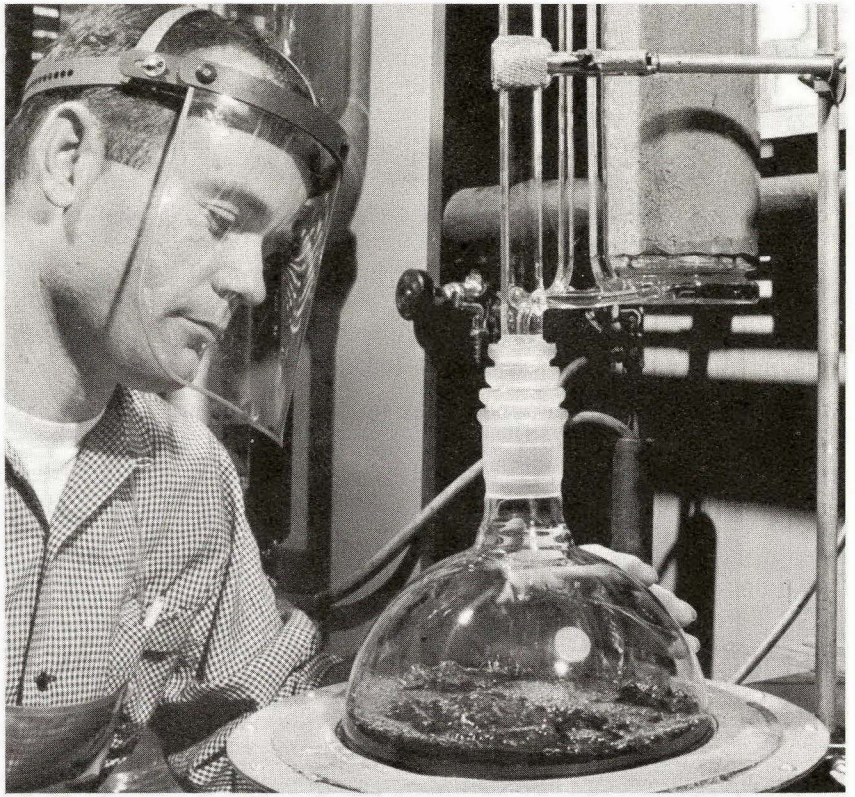
Wood particle studies seeking improved strength and durability properties of particle board, improved adhesives, the forming of products made of wood particles, and improved mixed-species utilization.

D. *Processing of Wood*

Processing research involves wood machining, the applied aspects of wood drying, and the mechanical and chemical operations involved in conversion of wood and wood residues into products. Particular emphasis on the young growth timber resource is required. Needed studies:

Machining research to develop thinner saws with long operating life, improved tool cutting edges, improved surface quality of the machined product, improved stability of cutting tools, and noise reduction in machining operations.

Studies to work out improved drying schedules, economics of predryer use, platen drying of thin wood products, and solvent drying.



Studies of mechanical and chemical process operations to develop techniques for mechanically or electronically sensing properties of wood required for quality classification and ways to improve pulping and extraction of resins and like materials with lower costs for power and chemicals and more efficient recovery of both principal products and byproducts.

E. *Wood Protection*

Studies of ways to protect wood in use determine the biological, physical, and chemical factors that influence wood durability. Research needs include:

Identification of fungi that attack logs and wood products.

Methods for detection and control of fungi.

Effect of fungal attack on wood and the influence of tree species characteristics.

F. *Brush Species Utilization*

Little is known of the possibilities for economic use of brush species that dominate millions of acres of wildland. To explore this field, research should:

As a first step, investigate the physical and chemical properties of species.

Followup with studies of potential uses suggested by these initial investigations.

G. *Wood Quality*

Research in wood quality spans a wide range of studies in the forest, industrial plants, and laboratories. Needed are:

Development of improved log grades reflecting more closely the quality of products which can be produced.

Determination of lumber grade output by log grades for important softwood and hardwood species.

Investigation of the way wood quality is related and such features and characteristics as to cell and tissue structure, summerwood-springwood ratios, and specific gravity.

Elevation of existing forest stands in terms of specific gravity.

Development of procedures to predict in young stands their wood quality at maturity.

H. *Wood Engineering*

Engineering studies seek knowledge required for more effective use of wood in construction. Needed are:

Improved engineering design of wood structures and building components.

Tests of stressed-skin construction and other approaches for roof, wall, and floor systems.

RANGE MANAGEMENT RESEARCH

A. *Characteristics and Requirements of Range Vegetation*

Use and management of range vegetation to its full efficiency depends upon adequate knowledge of the interrelationships between plants and their environment. Research needs include studies of:

Requirements of range plant species for heat, moisture, and nutrients.

The nature of competition between plants. Vegetational changes, both natural trends and those induced by man's activities.

Genetics of the important plants.

Nutritive values and digestibility of forage species for livestock and game.

Methods of sampling complex assemblages of plants so that adequate data can be obtained with a minimum of effort.

B. *Livestock-wildlife-vegetation Relationships*

Research should determine how domestic livestock and wild animals may be managed together on the same areas and what their interrelationships with the vegetation are. Needed studies include:

The effects of rodents on vegetation.

How to control destructive insects and encourage beneficial ones.

The effects of animals on watershed protection and management.

How to reduce damage to tree reproduction caused by grazing animals.

C. *Management Systems for Livestock and Big Game Ranges*

The development of improved, new grazing systems and the testing of existing ones, such as rotation, deferred, yearlong, and rest-rotation grazing, are essential features of research on livestock and big game ranges. Needed are:

Evaluation of responses to grazing in terms of vegetation and animal production and in trend of range condition.

Analysis of costs and returns wherever possible.

Studies of means to correlate grazing under each system with other land uses and values.

D. *Improvement Practices for Grass and Brush Ranges*

The development and testing of range improvement practices is largely concerned with seeding, fertilization, and the manipulating of existing undesirable vegetation with fire, chemicals, and mechanical and biological means. Studies in this field should include:

Search for new species and varieties of plants, testing of their adaptability to various sites and conditions, and development of suitable seeding practices.

Determination of the best time to apply fertilizers on range lands and the amount required for sustained high forage and animal production, for different sites and soil types.

Discovery and testing of chemicals and means of application, uses of fire, mechanical devices, and biological agents which will be effective in reducing or removing and controlling undesirable vegetation and in encouraging desirable plant species. The greatest need is to develop specifications for each type-conversion practice as to where, when, and how it should be used.

WATERSHED MANAGEMENT RESEARCH

A. *Watershed Management in California Brushlands*

To make the most of California's brush-covered watersheds—and of those in snowpack and commercial timber zones—research must include both basic and applied studies. Research in watershed hydrology gathers basic information on climate and precipitation, water yield and sedimentation, infiltration and evaporation. Applied studies followup this basic work with trials of management of watershed slopes and stream courses, including practices designed to modify vegetation, stabilize slopes and channels, and rehabilitate burned watersheds.

For watershed management of brushlands adjacent to urban areas, additional research emphasis should be given to:

Methods of decreasing erosion rates on brush-covered slopes.

Manipulation of the brush cover and its effect on flood runoff.

Use of water by various types of brush and methods for lessening this use.

Pilot testing of watershed management techniques in the various vegetation types characteristic of southern California.

For watershed management of brushlands adjacent to rural areas the needs include:

More information on soil moisture use by various types of brush and on ways of manipulating the use.

Determination of the effect of conversion of brush to timber or grass.

Pilot studies of promising watershed management practices.

B. *Watershed Management in California's Snow Zone*

Snowpack research includes studies of: Meteorology and snow accumulation and melt; amount and timing of water yield from various parts of watersheds; the effect of forest types and sites on water yield; methods of increasing or delaying water yield, minimizing sedimentation and local floods, and maintaining water quality; and pilot tests of promising watershed management measures. To implement this program:

Meteorology and snow physics research should be strengthened, especially studies of methods for drifting snow and studies of the effects of wind on snow melt.

More attention should be given to water yield and streamflow studies, including research on soil moisture storage regimes, winter evapotranspiration losses, and methods of treatment of nonforest sites.

Whole watersheds should be set aside and calibrated for pilot studies of management measures.

C. *Watershed Management in California's Commercial Timber Zone*

Research in the commercial timber zone follows a pattern somewhat like that in the snow, including studies of: precipitation, soil moisture regime, sedimentation, and streamflow on experimental watersheds; the effect of forest stands, fire, and cutting, on water yield and flood flows;

the effect of logging roads and trails and other treatments on runoff patterns; methods for improving water yield, and minimizing sedimentation and floods; pilot tests of promising management measures. Needs include:

Establish and calibrate pilot watersheds representative of the main timber and soil types in the lower elevation commercial timber zone, where rain is the principal form of precipitation.

Start studies of precipitation, soil moisture regimes, sedimentation, and streamflow.

Develop additional information on methods of increasing water yield, delaying water yield, and minimizing sedimentation and local floods.

As soon as possible test results obtained from small-scale studies by full-scale application on calibrated whole watersheds.

FOREST RECREATION RESEARCH

A. *Research in Recreational Land Management*

Recreational land management research includes studies and analyses of the alternatives open to managers of particular recreational areas, public or private. Specifically, research is needed to:

Determine the impact of specific types of activities on specific types of environment.

Analyze the capabilities of different environments to maintain and regenerate themselves under heavy recreational use.

Develop natural and artificial measures for protecting the recreational resource base.

Formulate guidelines for forest recreation planning and management.

B. *Research in Recreational Policy, Institutions, and Economics*

Research in recreational policies, institutions, and economics investigates the characteristics of demand for recreation services and facilities, and the nature and variability of the factors affecting demand. This information is of fundamental significance to public decision makers, managers of large private wildland holdings, and the recreation industry as a whole. And it can help individual firms in the recreation industry choose their location and scale of operations. Research needs include:

Studies to determine the degree to which specific recreation activities require or preempt the use of wildlands.

Analyses of benefits and costs of recreation developments.

Studies of the relationship between forest recreation and the local economy.

Studies of effects of price levels and methods of levying charges.

Evaluation of the factors affecting demand for recreation services and facilities.

Analysis of rates of return to private investments in forest recreation enterprises.

WILDLAND ECONOMICS RESEARCH

A. *Collection of Basic Economic Statistics*

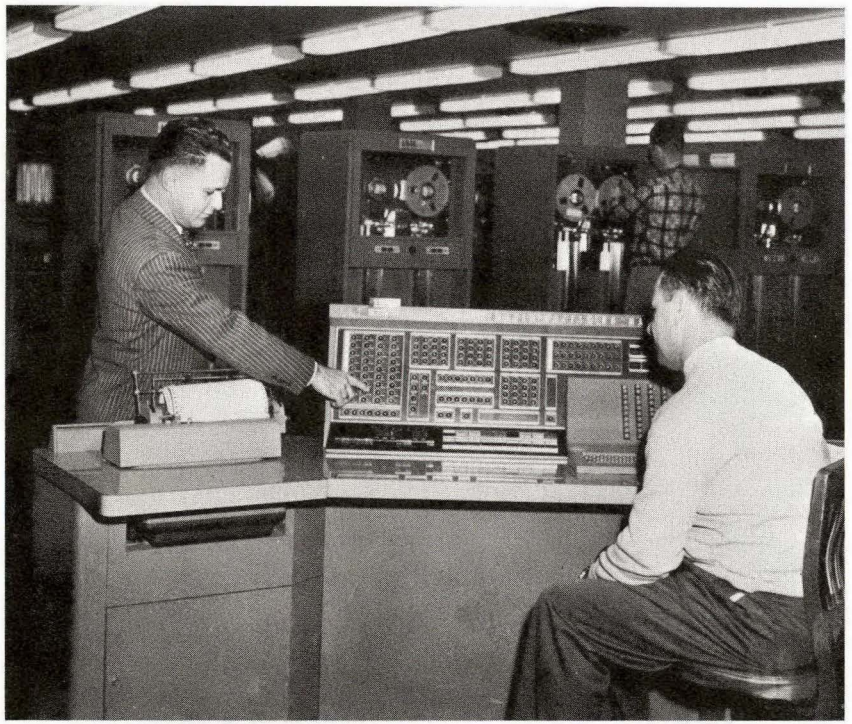
The growth of competing uses for wildland creates an ever-increasing need for resource information. Examples of this need are requests

for statistics to use in Rural Area Development proposals, a State economic planning project, and reappraisals of the timber resource situation. Research should:

Develop methods for more effective analysis and use of basic resource statistics. Solution of many business and economic problems depends on more detailed, more localized information—timber volumes and growth, industrial output, and production trends. This will require adaptation of the most modern means of compiling and analyzing large quantities of data, and of retrieving the results for appropriate uses.

B. *Economics of Production*

Solutions for technical problems provide new techniques to increase the output of wildland resources. They also often create difficult choices among alternative management practices. Research in the economics of production can give managers a broader base for decision. Such research should:



Determine the costs of alternative methods of management and the returns to be realized from applying these methods.

Develop an analytical framework for wise choices among new techniques.

C. *Analysis of the Wildland Economy*

Besides alternative management practices, there is opportunity for alternative uses of wildland. Consequently, conflicts can arise—not only between recreation and timber, for example, but also between water, forage, and all other uses. The conflicts may become policy problems. To help weigh alternatives such as these and resolve conflicts in use, economic studies are needed in three fields:

1. Marketing and utilization. Studies of markets and of the economics of utilization are needed as a foundation on which to build new and enlarged markets for existing wildland products and for residual materials which remain unutilized under current market conditions.

2. Taxation, Credit, and Insurance. These and related institutions often have very important impacts on the way wildlands are managed. Particularly in view of the strong influence of public policies on these institutions, research is needed to make certain that such policies do not unnecessarily obstruct good management practices.

3. Demand for Wildland Products. Because of the long time period involved in production of timber and certain other wildland products, careful and continuous appraisals are needed of the factors affecting demand for these products and of the long-term trends in such demand. These appraisals provide essential information for such key decisions as the best use of land, the proper intensity of management and protection, and the wise limits of investment in wildland conservation activities.

D. *Wildland Benefits and Costs to the Economy at Large*

If newly developed techniques are really better than what we are already doing, the additional benefits they bring should exceed the additional costs of putting them into effect. But to decide the worth of new practices requires more than knowledge of direct financial costs.

Research must also determine the broader economic consequences of new practices—their nonmonetary benefits and costs, and their effects on employment, wages, incomes, and tax revenues. This type of analysis is particularly essential for proper evaluation of public programs dealing with wildland protection and management.

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